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Title: Next Generation Visualization Displays: The Research Challenges of Building Tiled Displays

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Next-Generation Visualization Displays: The Research Challenges of Building Tiled Displays

Organizers:
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Panelists:
James P. Ahrens, Los Alamos National Laboratory
Kai Li, Princeton University
Daniel A. Reed, University of Illinois

Motivations and Key Issues

Tiled displays (multiple projector arrays) are quickly becoming technologically viable options for constructing high-end displays at a reasonable cost. Tiled displays address the need for increased resolution, increased field of view, large-scale form factor for group-oriented visualization and provide possible mechanisms for scaling graphics performance and leveraging commodity technologies. Numerous research groups are currently investigating tiled display technologies and their use in visualization applications. While tiled displays have a lot of potential to offer the visualization community, there are still many open research questions that limit their adoption. This panel will discuss the current state-of-the-art and open research issues related to tiled displays in the areas of applications, compute systems, display surfaces, projectors, and overall architecture of complete systems. Some of the questions that will be addressed include:

- What current technologies are appropriate for constructing tiled display environments suitable for serious visualization applications?
- What are some of the limitations of current tiled display technologies and architectures and what might be done to overcome these limitations?
- What are some novel approaches to exploiting the wide field of view and ultra high resolution that is possible with large-format tiled displays?
- How much resolution is really needed for effective visualization of today's datasets?
- Do we have a scientific basis for designing multi panel (tiled) display environments and effectively exploiting them?
- What opportunities do tiled displays open up for developing advanced visualization environments?
- What are some of the key research problems that must be addressed for widespread adoption of tiled display systems as a viable path for production visualization systems?
- What are some alternatives to tiled displays that can address some of the requirements for future visualization systems?

The panelists will address these and other issues, outline future developments, and encourage discussion and interaction on possible future uses and limitations of tiled display systems.

Position Statements

Our panelists address these issues in their position statements below; these positions will be presented during the panel and elaborated on in open discussion.

James P. Ahrens – Issues and Architectures for Commodity Graphics Clusters

Scientists are using computer simulations to resolve models of real world phenomena, such as models of the earth's climate and oceans, accelerator physics dynamics and many others. Tiled displays provide increased visual resolution for viewing visualized results of these extremely detailed scientific simulations.

To achieve acceptable frame rates at full display resolution, these displays are typically used for non-interactive movie playback. An open research question is whether three-dimensional interactive visualization of extremely large scientific datasets on these displays is possible.

Cost-effective tiled displays are typically built from commodity parts: a networked PC cluster with a graphics card and display projector attached to each node. Due to their size, large scientific datasets need to be partitioned into independent subsets on the nodes of the PC cluster. Thus, the problem of visualizing partitioned data and rendering it to the appropriate tile can be characterized as a parallel sorting problem. Possible options for data to be sorted include portions of the input dataset, generated polygons or z-buffered images. An interactive solution to the sorting problem is limited by the available network bandwidth and/or the graphics cards I/O bandwidth. Given this architecture and its limitations, questions of interest include; what software algorithms are most efficient? (for example, what should be sorted and when?), is additional hardware needed? (for example, are specialized compositing networks or framebuffers useful?), and if so, how can this hardware work with commodity solutions? Current and possible future approaches for solving this problem will be described and discussed.

Kai Li - What's Wrong with Commodity Presentation Projectors in Building a Tiled Display System?

Many design goals of the commodity presentation projectors are different from those required for building a tiled display system. I would like to convey some of the experiences we have in building the Scalable Display Wall system at Princeton and state the challenges for the projector industry to help us build good, tiled display systems.

Daniel A. Reed - Smart Spaces: Large-scale Displays and Mobile Interaction

The confluence of ubiquitous wireless networking; powerful wearable, handheld, and embedded computer systems; lightweight head-mounted displays; high-resolution digital video; immersive virtual environments; and scalable tiled displays provides a powerful technology base for augmenting human intellectual and sensory capabilities. In the home and office environment, as well as in shared public spaces, ubiquitous, intelligent devices will unobtrusively share data, preferences, and work or recreational contexts about each user. User movement among environments and contexts will trigger dynamic reconfiguration (e.g., shifting from shared video conference to private work mode) as well as information modality transformation (e.g., high-resolution video of breaking news in a conference room with tiled displays to tickertape headline updates on a PDA or two-way pager). We will summarize our work building an intelligent, responsive conference room that combines tiled displays supported by Linux clusters and intelligent devices.

Rick Stevens -- Using Tiled Displays to Build High-resolution Projection Based Virtual Realty Systems

Our original motivation for exploring tiled displays was to find a way for constructing higher-resolution projection based virtual reality environments. We imagined replacing the moderate resolution CRT based projectors in our CAVE and ImmersaDesk systems with compact arrays of commodity projectors. In the process of exploring this path we have both encountered significant technology challenges (e.g. image blending, color matching and calibration, scalable parallel display architectures, stereo support, and screen technologies) as well as encountering pleasant surprises (e.g. users like large-format tiled displays even with imperfect image quality, commodity technologies are not significantly more difficult to adapt to drive high-performance displays than traditional high-performance systems, non-immersive uses of large-format tiled displays may be as or more compelling than VR for certain types of visualization tasks). We believe that tiled displays represent a generalization of projection based display environments that will have a broad impact on both immersive and non-immersive systems and perhaps represents a new paradigm for developing non-desktop based visualization systems. These room-oriented systems may require not only a new user interface metaphor (the desktop metaphor no longer works very well), but may also hint at a dramatic new application interface modality appropriate for interactive human based visualization environments that will ultimately become ubiquitous delivery vehicles for a variety of scientific and information visualization applications.

Biographical Sketches of Panelists

James P. Ahrens

James P. Ahrens is a technical staff member at Los Alamos National Laboratory. He works in the Advanced Computing Laboratory as part of the Visualization Group. He received a B.S. in computer science from the University of Massachusetts at Amherst in 1989 and a Ph.D. in computer science in 1996 from the University of Washington in Seattle. He is the project leader at Los Alamos for ASCI VIEWS visualization research and development and the technical lead for an ASCI VIEWS project on high-performance visualization components. His research interests include algorithms, systems and architectural approaches for visualizing extremely large scientific datasets.

Kai Li

Kai Li received his Ph.D. degree from Yale University in 1986. Since then, he has been an assistant, associate and full professor of the department of computer science at Princeton University. He was elected to be an ACM Fellow in 1998.

His research interests are in operating systems, computer architecture, fault tolerance, parallel computing, and immersive systems. He is the creator of the concept and software shared virtual memory also called distributed shared memory. He led the SHRIMP project at Princeton, which explores the research issues of how to build high-performance servers using clusters. He is leading the Scalable Display Wall project at Princeton, which studies how to build and use large-format, inexpensive display systems.

Michael E. Papka

Michael E. Papka is a staff member of Argonne's Futures Laboratory and a Fellow at the Argonne/Chicago Computation Institute. He received a B.S. in Physics from Northern Illinois University in 1990 and an M.S. in Computer Science in 1994 from the University of Illinois at Chicago. Since 1995, he has been a Ph.D. student at the University of Chicago. His research focuses on methods of scientific visualization as applied to advanced display technology. Papka is co-investigator both in the Advanced Visualization Technology Center and DOE NGI Corridor One project. He also was a key participant in the DOE Grand Challenge Application on Virtual Materials.

Daniel A. Reed

Daniel A. Reed is currently Professor and Head of the Department of Computer Science at the University of Illinois at Urbana-Champaign. In addition, he is Director of the National Computational Science Alliance, one of the two NSF PACI consortia. He is also a member of the steering committee for the DOE/ASCI ASAP Center for Simulation of Advanced Rockets (CSAR) at the University of Illinois. Dr. Reed received his BS (summa cum laude) in computer science from the University of Missouri at Rolla in 1978 and his MS and Ph.D., also in computer science, from Purdue University in 1980 and 1983. He is the author of more than 100 research papers and monographs on algorithms, architectures, and performance evaluation techniques for high-performance computing and virtual environments.

Rick Stevens

Rick Stevens is a Professor in the Computer Science Department at The University of Chicago, Division Director of the Mathematics and Computer Science at Argonne National Laboratory, and co-Director of the Argonne/Chicago Computation Institute. He also heads the Computing and Communications Infrastructures Futures Laboratory (aka Futures Lab), a research group whose goal is to develop multimedia collaborative environments, virtual reality and advanced computing technologies, and demonstrate these on advanced scientific applications. He is exploring the use of virtual reality in the visualization of scientific data and processes. His efforts include improving displays, recording, and playback of virtual reality experiences; developing new methods for tracking and control and close coupling with parallel supercomputers; and devising new ways of collaborating in virtual environments. Of particular interest to him is teleimmersion --strategies for synthesizing networking and multimedia technologies to enhance the development of wide-area collaborative computational science.

Next Generation Visualization Displays: The Research Challenges of Building Tiled Displays

James Ahrens
Los Alamos National Laboratory

Introduction

- **Starting point:**
  - Using commodity PC clusters with commodity graphics cards to drive large tiled displays
  - What applications will run efficiently on these clusters?
    - 2D based applications – movie playback, large office desktop

Introduction

Starting point:

- Using commodity PC clusters with commodity graphics cards to drive large tiled displays

- What applications will run efficiently on these clusters?
  - 2D based applications – movie playback, large office desktop

Motivation

Tiled displays are useful for displaying the results of 3D visualization of extremely detailed scientific applications

- Visually analyze results at higher display resolution
  - Reduces aliasing
- Increase collaboration

Introduction

- Can we use tiled displays for interactive visualization of extremely large scientific datasets?

Issues

- Scalable display size
- Scalable rendering

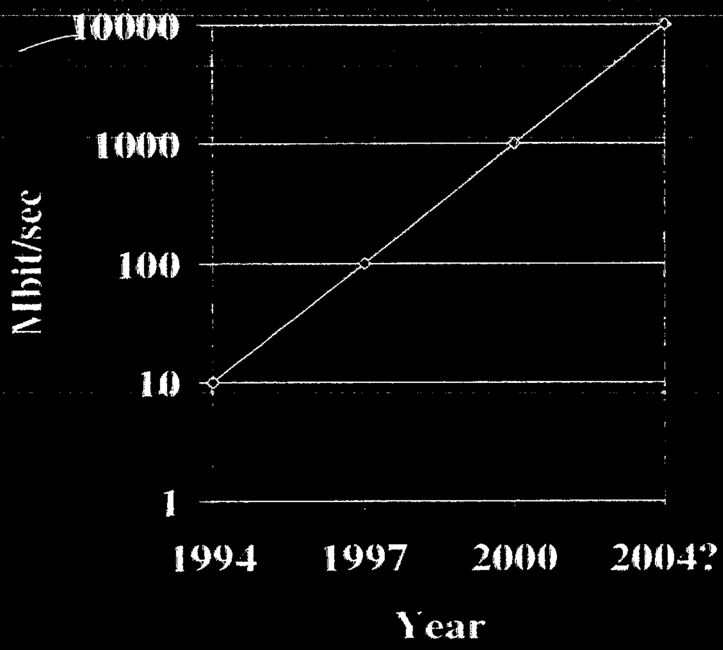
Overview

Properties of commodity components
- network
- graphics cards
- internal buses

Parallel rendering solutions
- Sorting
- Data replication
- Software / hardware

Properties of commodity networks

Ethernet performance for PC clusters



Improving at an exponential rate

Optimistically:

- 1 Gbit per second today

- 125 MB per second

Good news!

Properties of commodity graphics cards

- SGI Infinite Reality class commodity graphics cards today
- 2 to 3 orders of magnitude cheaper than an IR
- Improvement at an exponential rate
  - driven by gaming market

Good news!

Internal PC buses and drivers

Hardware:

- PC internal architecture has remained the same for many years
  - As networking and graphics cards evolve will internal bandwidths keep up?

Software:

- Direct X is driving graphics card development
  - Buffer readback will be depreciated in next release
- Will there be hardware support for operations required for parallel rendering?
  - Access to depth buffer?

Bad news!

Sorting classification

- **[Molnar et al], “A sorting classification of parallel rendering”, CG&A, July 1994.**

Graphics Primitives

| ← Sort-first

Geometry Processing

| ← ~~Sort-middle~~

Rasterization

| ← Sort-last

Display

Data replication

- If data is replicated is does not need to be sent...

Replication

Graphics Primitives

Geometry Processing

Rasterization

Display

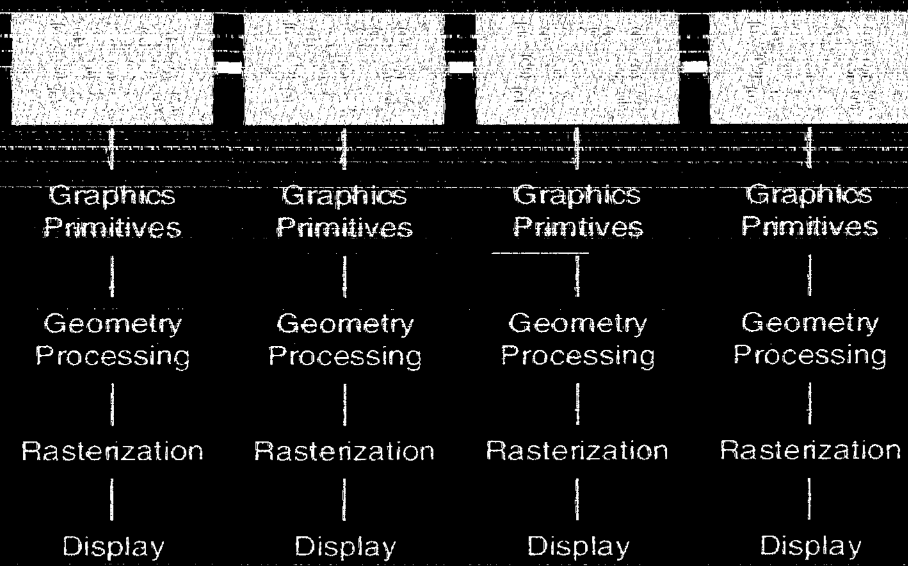
Data replication supports scalable display sizes

Algorithm

- Replicate all graphics primitives on each graphics node
- Screen space partitioning
- No communication required after setup

Limitations

- For setup - the network
- Not scalable rendering
  limited by the performance of a single graphics node



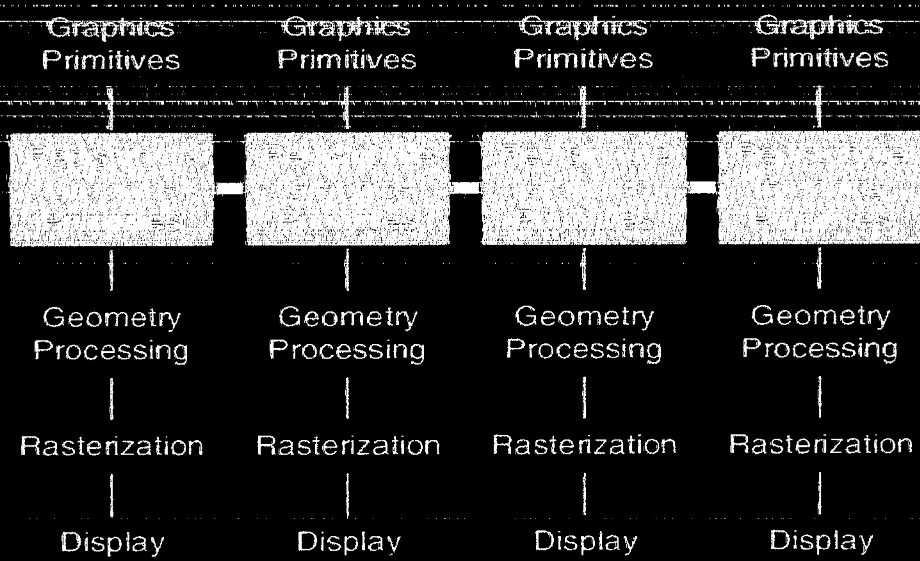
Sort-first supports scalable rendering

Algorithm

– No replication of graphics primitives
– Screen space partitioning
– Transfer graphics primitives before each render

Limitations

– Data transfer over the network
    worst case need to transfer a significant percentage of primitives



Possible data transfer sizes for replication and sort-first solutions

Simulation size / Number of triangles	Size in MBs (40 bytes per vertex)	Size in MBs at 10 frames per second
1000^3 -> 1M	40 MB	400 MB
2000^3 -> 4M	160 MB	1600 MB
4000^3 -> 16M	640 MB	6400 MB
8000^3 -> 64M	2650 MB	26500 MB

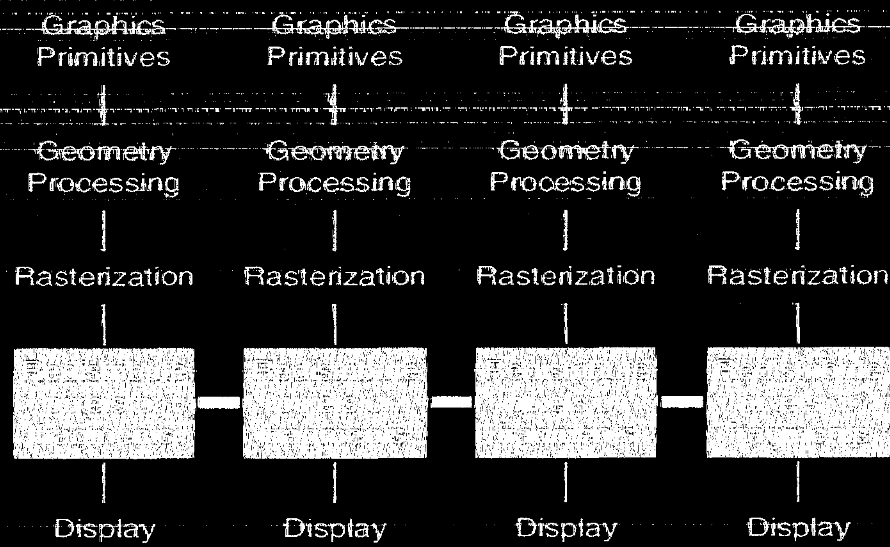
Sort-last supports scalable rendering

Algorithm

- No replication of graphics primitives
- Graphics primitives partitioning
- Composite depth images after each render

Limitations

- Data transfer over the network
  - worst case need to transfer full image size



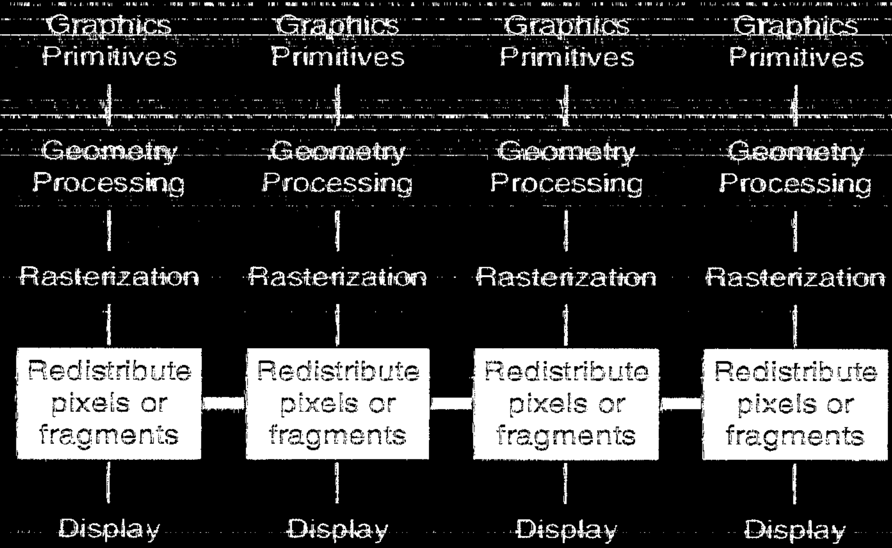
Possible data transfer sizes for a sort-last solution

Depth-buffered image size	Size in MBs (8 bytes per pixel)	Size in MBs at 10 frames per second
1000x1000	8	80
2000x2000	32	320
4000x4000	128	1280
8000x8000	512	5120
10000x10000	800	8000

Sort-last hardware – custom compositing networks

Algorithm
- Composite depth images after each render
- Use custom hardware
- Possibly direct connection to graphics card
- Independent network

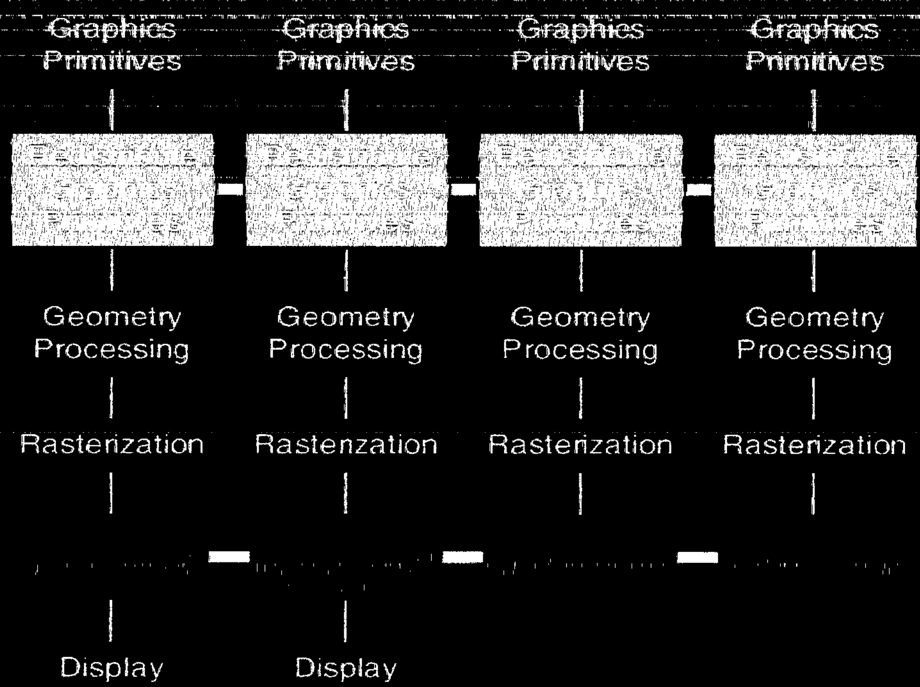
Limitations
- Market viability
  - Cost
  - Updates
  - Performance



Additional issue – custom hardware framebuffers

- **Problem**
  - **Using more graphics nodes than displays requires communicating image tiles to final location**
- **Solution**
  - **Collect image tiles in a framebuffer; use framebuffer to interface to displays**

Sort-first with tiled display

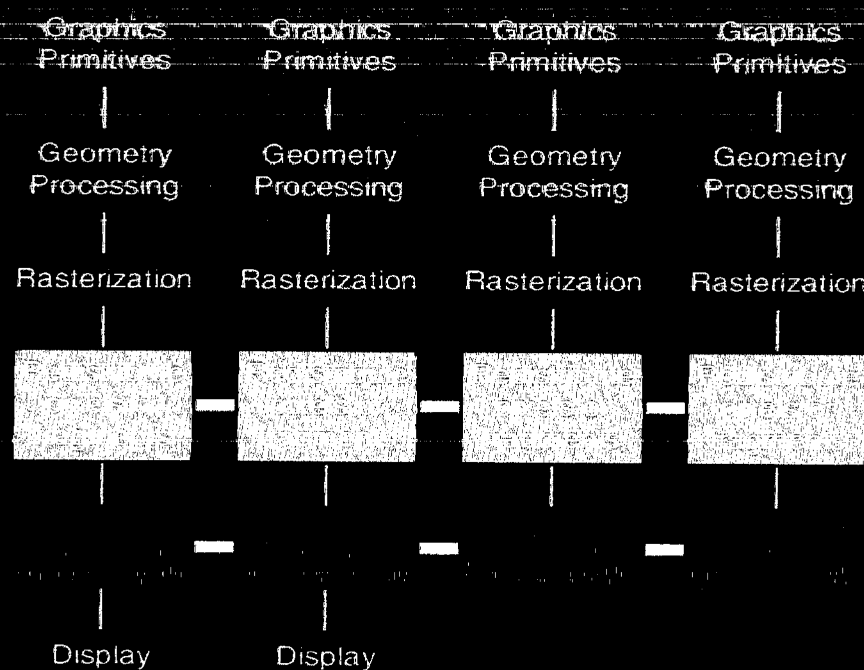


Additional issue – custom hardware framebuffers

Limitations & Questions

- Market viability
  - Cost
  - Updates
  - Performance
- Use commodity networks instead?
- For sort-last, can communication steps be merged?

Sort-last with tiled display



Summary

Can we use tiled displays for interactive visualization of extremely large scientific datasets?

- For the foreseeable future, commodity networks and PC buses will make this very challenging

Future areas:

- Sort-first hardware
- Dynamic partitioning
- Combination of solutions
  - Sorting
  - Data replication
  - Software / hardware